Anisotropic Properties of Compacted Clay-Rich Rocks

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RESEARCH OBJECTIVES

The principal objective of this work is to characterize the elastic anisotropic properties of clay-rich rocks for consolidation conditions simulating compaction at depth. A novel consolidation cell containing sets of ultrasonic transducers and a phased array has been designed to allow measurement of the five transverse isotropy (TI) elastic constants of a rock sample during compaction. During the testing phase of this project, we will conduct a series of laboratory anisotropy tests on clay-rich rock samples provided by our industry partners from basins worldwide.

APPROACH

The standard laboratory ultrasonic transmission method for measuring the five elastic constants of rock with TI requires a minimum of three oriented cores taken parallel, perpendicular, and at an angle to the bedding. This method is unsuitable for measuring the stress-induced TI elastic constants of clay-rich rocks during compaction because: (1) the process of unloading-recoring-reloading is time consuming, and (2) it is difficult to realize the same stress state in the sample cored at an angle to the bedding. The apparatus developed in this project utilizes a P-wave phased array and three sets of polarized ultrasonic transducers to recover the five TI constants during uniaxial strain consolidation.

ACCOMPLISHMENTS

A series of ultrasonic tests on clay-rich rocks provided by ChevronTexaco were performed to determine the attenuation of P- and S-waves in the 200 kHz to 2 MHz range. These tests were carried out on clay samples compacted under drained, uniaxial strain conditions to axial stresses of 2.5 MPa. Based on these results, the design of the compaction cell, the P-wave phased array, and the ultrasonic P- and S-wave transducers were finalized.

A schematic of the compaction cell, including the locations of the phased array and the ultrasonic transducers, is shown in Figure 1a. The cell accommodates an approximately 2 cm thick clay sample in a slot with the geometry and dimensions given in Figure 1b. A pair of 1 MHz P-wave transducers are used to directly measure c_{11}—P(0°) in Figure 1b. Two sets of 40 kHz S-wave transducers with polarizations parallel and perpendicular to the bedding direction— SH(0°) and SV(0°), respectively, in Figure 1b—provide direct measurements of c_{44} and c_{66}. A 1 MHz, 32-element P-wave phased array and a P-wave pinducer (Figure 1a) are used to obtain c_{33} and c_{13} from plane P-wave measurements made over a range of angles (0° to approximately 60°).

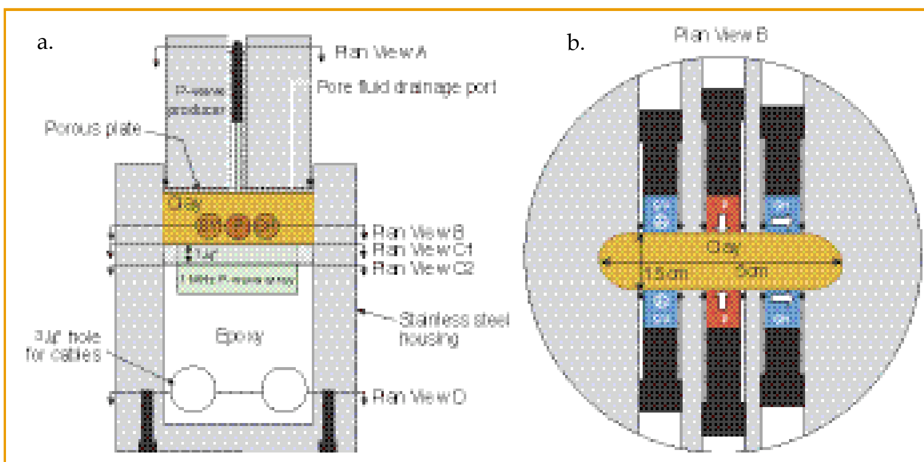

Figure 1. Schematic of the compaction cell for clay anisotropy measurements: (a) view in cross section showing the locations of the P-wave phased array and pinducer, and (b) plan view illustrating the location of the clay sample and the P- and S-wave transducers

SIGNIFICANCE OF FINDINGS

The apparatus developed in this project utilizes a pair of P-wave transducers, two pairs of polarized S-wave transducers, and a P-wave phased array to recover the five TI constants during uniaxial strain consolidation. Because the measurements are performed during consolidation without the need for unloading-recoring-reloading, the apparatus can be used to investigate the development of stress-induced anisotropy in geomaterials such as clay-rich rocks and benthic sands. We anticipate that this apparatus will prove useful in investigations of the anisotropic properties of soft sediments relevant for oil and gas imaging in sedimentary basins, and for the characterization of the shallow sea floor.

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